IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Application No :

U.S National Serial No. :

Filed :

PCT International Application No. : PCT/FR2004/002906

VERIFICATION OF A TRANSLATION

I, the below named translator, hereby declare that:

My name and post office address are as stated below;

That I am knowledgeable in the French language in which the below identified international application was filed, and that, to the best of my knowledge and belief, the English translation of the international application No PCT/FR2004/002906 is a true and complete translation of the above identified international application as filed.

I hereby declare that all the statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the patent application issued thereon.

Date: April 26, 2006

Full name of the translator : Roger Walter GRAY
For and on behalf of RWS Group Ltd

Post Office Address : Europa House, Marsham Way,
Gerrards Cross, Buckinghamshire,
England.

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International publication date
2 June 2005 (02.06.2005)

PCT

(10) International publication number
WO 2005/048808 A2

(51) International patent classification[7]: A61B

(21) International application number: PCT/FR2004/002906

(22) International filing date: 12 November 2004 (12.11.2004)

(25) Language of filing: French

(26) Language of publication: French

(30) Data relating to the priority:
03/13,263 13 November 2003 (13.11.2003) FR

(71) Applicant and
(72) Inventor: **BROTTIER, Yves, Vincent** [FR/FR]; 2, rue de Buzenval, Hall A, F-92210 Saint Cloud (FR)

(72) Inventor; and
(75) Inventor/Applicant *(US only)*: **HUGUENY, Alain, Marie** [FR/FR]; 34, rue Jeanne d'Arc, F-69003 Lyon (FR)

(74) Representatives: VOUGNY, Christophe et al; Cabinet Plasseraud, 65/67, rue de la Victoire, F-75440 Paris Cedex 9 (FR)

(81) Designated states *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

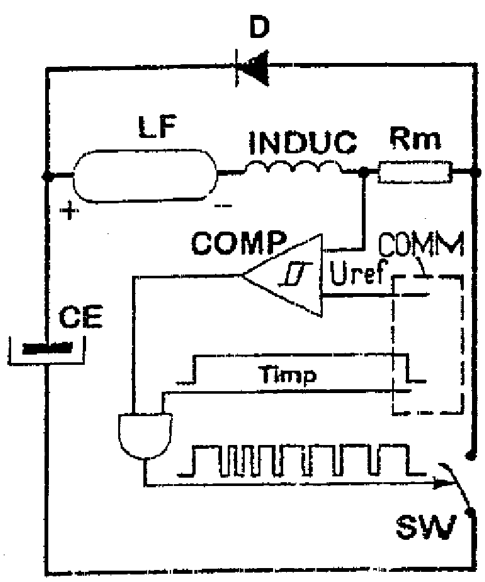
(84) Designated states *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO patent (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE,

[continued on next page]

As printed

(54) Title: HAIR-REMOVAL DEVICE AND METHOD OF USING ONE SUCH DEVICE

(54) Titre : APPAREIL D'EPILATION ET PROCEDE DE MISE EN OEUVRE D'UN TEL APPAREIL



(57) Abstract: The invention relates to a hair-removal device which is intended for local skin application. The inventive device is designed to emit at least one light pulse which is generated by an electric current impulse that passes through a flash lamp (LF) such as to form an electric arc, said current originating from the discharge of a capacitor (CE) and being controlled by a fast-switching electronic switch (SW). According to the invention, the aforementioned three elements are disposed in a main loop (CE-SW-LF). During each capacitor discharge, the current passing through the lamp generates a measurement signal (URm) which is representative of said current and which is compared to a reference value (Uref) by a hysteresis comparison device (COMP), in order to control the open or closed state of the switch and to adjust the current by means of the high-frequency cut-off thereof around a determined intensity (Icritic) throughout essentially the entire duration of the current impulse.

(57) Abrégé : Appareil d'épilation pour applications cutanées et locales, adapté pour émettre au moins une impulsion lumineuse générée par une impulsion de courant électrique traversant une lampe flash (LF) en y formant un arc électrique, ce courant provenant de la décharge d'un condensateur (CE) et étant commandé par un interrupteur électronique (SW) à commutation rapide, ces trois éléments étant disposés en une boucle principale (CE-SW-LF). Pendant chaque décharge du condensateur, le courant traversant la lampe génère un signal de mesure (Urm) représentatif du courant, qui est comparé à une valeur de référence (Uref) par un dispositif de comparaison à hystérésis (COMP) pour commander l'état ouvert ou fermé de l'interrupteur et réguler le courant par son découpage haute fréquence autour d'une intensité déterminée (Icritic)

2005/048808 A2

BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LU, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG)

Declaration according to Rule 4.17:

— *of inventorship (Rule 4.17(iv)) for the following designation US*

Published:

— *Without international search report and to be republished upon receipt of that report*

For an explanation of the two-letter codes and the other abbreviations, reference is made to the explanations ("Guidance Notes on Codes and Abbreviations") at the beginning of each regular edition of the PCT Gazette.

HAIR-REMOVAL DEVICE AND METHOD OF USING ONE SUCH DEVICE

The present invention relates to hair-removal devices for local skin application, designed to emit at least one light pulse generated by an electric current pulse passing through a flashlamp forming an electric arc therein, this current coming from the discharge of at least one capacitor and being controlled by a fast-switching on/off electronic switch, these three elements being placed in a main loop. The term "light pulse" is understood to mean a pulse of visible and/or infrared (V/IR) radiation, in general generated by a xenon flashlamp.

All these devices produce pulses having a duration of between 5 and 50 ms (milliseconds), this being exceptionally long for a flash and having, for this reason, specific regulation problems.

It is known from experience that skin response is better if the V/IR light pulses have quite a square waveform, with a relatively stable instantaneous power over their entire duration. Among existing devices coming close to meeting these characteristics, mention may be made of trapezoidal-discharge devices comprising, in a loop, a capacitor, a switch and a flashlamp.

The two major drawbacks of trapezoidal-discharge devices are the high stressing of the flashlamp and the overdesigning of the capacitor. With regard to high stressing, the flashlamp is either of ordinary, inexpensive construction made of a borosilicate - also commonly called PYREX - it is rapidly worn out and has to be often replaced, or it is manufactured from quartz in order to provide a longer lifetime, but at a much higher price. As regards the capacitor, it is necessary

to overdesign this in current devices in order to limit the decrease in power during the pulse. This overdesigning has the drawback of substantially increasing the manufacturing cost of the devices, and also both their volume and their weight.

The object of the present invention is to reduce the stressing of the flashlamp and to substantially improve the utilization factor of the capacitor, while keeping a relatively stable instantaneous power during the V/IR light pulse.

For this purpose, one subject of the present invention is a hair-removal device of the aforementioned type, characterized in that, during each discharge of the capacitor, the current passing through the flashlamp generates a measurement signal representative of said current passing through the flashlamp and in that said measurement signal is compared with a reference value by a hysteresis comparator in order to set said switch in the open or closed state and to regulate said current passing through the flashlamp by its high-frequency cutoff around a defined current through substantially the entire duration of said current pulse.

Thus, the current is actively regulated during the brief moment while the current pulse lasts, thereby making it possible to deliver a light pulse of substantially constant power suitable for obtaining good skin response. Unlike the devices of the prior art, it is unnecessary to overdesign the capacitor, so that the voltage across its terminals varies little. In addition, this regulation limits the maximum value of the current passing through the flashlamp, and consequently the diameter of the electric arc, thereby preserving the flashlamp.

In preferred embodiments of the invention, one or more of the following arrangements may furthermore be employed:

- the measurement signal is a measurement voltage proportional to the current passing through the flashlamp, which voltage is delivered by a current-voltage transducer, said current-voltage transducer preferably being a resistor connected in series in the main loop, and the measurement signal is delivered in a direct and simple manner;

- a freewheeling diode is incorporated into an additional loop comprising, in common with the main loop, the flashlamp and the current-voltage transducer, thereby avoiding the appearance of an overvoltage that may damage the electronic switch;

- the main loop further includes an inductor, which reduces the rapidity of the current variation and makes it easier to regulate the current;

- the hysteresis comparator and the reference value are chosen so as to regulate the current passing through the flashlamp to a value substantially below the value of the current for which the expansion of the electric arc reaches the inner walls of the flashlamp, in order to preserve the lifetime of the flashlamp;

- said at least one capacitor is chosen so that the ratio of the initial voltage across its terminals before discharge to the final voltage at the end of the current pulse is between 2 and 6, and preferably about 4, so as to optimize the utilization factor of the capacitor and consequently to limit its capacitance;

- said at least one capacitor has a capacitance at most equal to 13 000 microfarads and a nominal voltage at most equal to 400 volts, said at least one capacitor preferably being an electrolytic capacitor;

- the capacitance of the capacitor is chosen so that the mean value of the current flowing through the flashlamp, measured over a period of one millisecond at the end of the current pulse, is between 90% and 100% of the mean value of the current measured over the same

period at the start of the current pulse, so as to obtain effective and pain-free hair removal;

- the electronic switch is chosen so as to have a switching time considerably shorter than one microsecond, said switch preferably being an IGBT;

- an electronic control module is designed to deliver the reference value to the hysteresis comparator and designed to deliver a current pulse in the main loop over a specified pulse duration, said pulse duration being between 20 ms and 45 ms, and preferably equal to about 35 ms in order to obtain a good compromise between hair removal and preservation of skin tissue;

- the control module is designed to introduce, into the fast-switching switch, a delay of specified duration at each opening of this switch, during which it is prevented from switching again to the closed state, the specified duration being significantly longer than the switching time of the switch but shorter than the time needed for the flashlamp to be turned off, and thus to prevent excessive overheating of the switch;

- the control module is designed so as not to cause a new current pulse to be emitted before a specified time, called the rest time, has elapsed since the preceding current pulse, the rest time being between one second and ten seconds, and preferably about seven seconds, this having a favorable influence on the size of the device and of its power supply;

- said at least one capacitor, the electronic switch and the hysteresis comparator are housed in the same casing, said casing having a volume of less than five liters; and

- the weight of the overall device is at most equal to two kilograms, so as to be easily transportable.

Another subject of the present invention is a method of employing a hair-removal device as defined above,

characterized in that it comprises, while generating the electric current pulse, the steps of:

- generating a measurement signal representative of the current passing through the flashlamp;
- comparing, with hysteresis, the measurement signal with a reference value;
- closing the electronic switch if the comparison between the measurement signal and the reference value indicates that the current passing through the flashlamp is below a specified current; or
- opening the electronic switch if the comparison between the measurement signal and the reference value indicates that the current passing through the flashlamp is above the specified current, so as to regulate said current passing through the flashlamp by high-frequency cutoff thereof around the specified current.

A preferred mode of implementing the method provides, each time the switch is opened, a delay step of specified duration, during which the switch is prevented from switching again to the closed state, the specified time being significantly longer than the switching time of the switch but shorter than the time needed for the flashlamp to be turned off.

In addition to the preceding description, the present invention will be better understood from the following description, given purely for illustration and implying no limitation, with reference to the drawings in which:

- figure 1 shows a basic diagram of a trapezoidal-pulse device of the prior art;
- figure 2 shows a U/t (voltage/time) plot of the voltage across the terminals of the capacitor of a device according to figure 1 during a trapezoidal pulse;
- figure 3 shows a P_{pulse}/t (instantaneous power/time) plot for the flashlamp of a device according to figure 1 during a trapezoidal pulse;

- figure 4 shows a diagram of a preferred embodiment of a device according to the present invention;

- figure 5 shows a U/t (voltage/time) plot of the voltage across the terminals of the capacitor of figure 4 during a pulse;

- figure 6 shows a P_{pulse}/t (instantaneous power/time) plot for the flashlamp of a device according to claim 4 during a pulse; and

- figure 7 is a perspective view of a hair-removal device according to the invention.

In what follows, the terms and abbreviations used have the following meanings:

- capacitor "CP" means one or more electrolytic capacitors, arranged in series or in parallel or series-parallel and intended for storing electrical energy, for the purpose of completely or partly reinjecting it into the flashlamp;

- pulse "V/IR" denotes the visible and/or infrared pulse intended to produce the hair-removal effect on the skin;

- switch "SW" denotes an electronic switch capable of rapidly switching;

- flashlamp "FL" means the flashlamp(s) arranged in series or parallel or series-parallel;

- U_i represents the voltage across the terminals of CP at the start of a pulse (U_i standing for initial voltage); and

- U_f represents the voltage across the terminals of CP at the end of a pulse (U_f standing for final voltage).

Figure 1 shows a flashlamp FL, a capacitor CP and a switch SW arranged in a loop. The switch SW is placed in the open or closed state by a rectangular pulse coming from a conventional electronic control module CON.

In figures 2 and 3, the operation of this device of the prior art is divided into three phases:

1. The flashlamp is lit when the capacitor CP has been charged to a voltage U_i. During this lit phase, the electric arc, firstly capillary and consuming a low current, naturally increases in diameter until it comes into contact with the internal wall of the flashlamp. This increase in diameter - or expansion - causes a corresponding reduction in the impedance of the flashlamp and therefore an increase in the current. The order of magnitude of the duration of this phenomenon is around 100 μs;

2. The flashlamp is kept in the lit state by keeping the switch SW in the closed state. Throughout this phase, the natural tendency of the arc to expand is prevented as it has already come up against the internal wall of the flashlamp - the arc is said to be confined. The current therefore no longer increases, rather it decreases because of the reduction in voltage across the terminals of the capacitor CP, which is being discharged. The physical contact between the electric arc and the wall of the flashlamp is a major element in the ageing of the latter. However, this contact is necessary in order to cause the electric arc to maintain, throughout the duration of the desired pulse, a small cross section, and therefore a relatively high impedance, and an instantaneous power within the desired limits despite the high voltage needed for operating the flashlamp. The order of magnitude of the power developed in the flashlamp during this phase is 10 kW, over a duration of several tens of milliseconds; and

3. The operation of the flashlamp is interrupted by the switch SW opening when the V/IR light pulse has lasted for the desired time. At this moment, the voltage across the terminals of the capacitor CP is U_f. The voltage U_f is lower than U_i because of the energy that the capacitor CP has injected into the lamp. Rapidly after the switch SW has opened, the electric

arc, which is no longer supplied, contracts on itself, its diameter decreases and it ends up by being extinguished. This phenomenon, the order of magnitude of the duration of which is around 100 μs, is extended by the inductance of the wiring or by an inductor optionally incorporated into the circuit.

The theoretical and empirical parameters that govern the power developed in a flashlamp operating in confined mode are such that the device of the prior art is equipped with flashlamps having a high AL/AD ratio (where AL is the arc length and AD is the arc diameter), generally of between 10 and 50.

It should also be understood that the instantaneous emission power of a flashlamp containing a confined arc is proportional to the voltage across its terminals U to the power 2.5, U being the voltage across the terminals of the lamp (certain formulae give even U to the power 3, but in the rest of this document, we base the numerical values mentioned by way of example on 2.5). Because of this relationship between the power and the voltage, and to ensure a reasonably small difference between the instantaneous power at the start of the V/IR light pulse and the instantaneous power at the end of the pulse, the difference between U_i and U_f must be very small, and only a small portion of the energy initially stored in the capacitor is used for the pulse so as to limit the drop in voltage across its terminals. The capacitor is underutilized and therefore must be of high capacitance. For example, in order for the instantaneous power to remain within ±10% of its nominal value, it is necessary to have $U_f = 0.92U_i$, and in this case, only 16% of the energy initially stored in the capacitor CP is utilized. Thus, to be able to deliver 100 J under the conditions described above, the capacitor CP must store 625 J before the start of a pulse. This represents an overdesign factor of 6.

As shown in figures 4, 5 and 6, the present invention consists in introducing current regulation into the hair-removal device 1 shown in figure 7, especially so that the electric arc maintains a cross section smaller than the internal cross section of the flashlamp, while still delivering the necessary power.

In this way, since the electric arc does not exert intense pressure on the internal wall of the flashlamp FL, it ages more slowly and, moreover, with current regulation, the flashlamp can remain at a substantially constant power throughout the duration of the V/IR light pulse, even if there is a large voltage difference between the start U_i and the end U_f of the pulse. This difference results in a high utilization factor of the capacitor CP, which thus no longer needs to be overdesigned.

Current regulation is chosen since, for a given flashlamp, with a confined or unconfined arc, operation at constant current corresponds to a very stable power, whereas operation at constant voltage corresponds to a relatively variable power.

As shown in figure 7, the device 1 includes a case 2 provided with on/off knobs 3 and control knobs 4 on its upper face, a handpiece 5 and a power cable 6 extending from the case to the handpiece. The handpiece 5 contains a xenon flashlamp and has a light output guide 7, and also a knob 8 for triggering the light pulse.

In figure 4, a preferred embodiment of the device according to the present invention is arranged as indicated below:

The main power circuit loop of the device, denoted by CP-SW-R_m-IND-FL loop, comprises the capacitor CP, a switch SW, a measurement resistor R_m, an inductor IND and the flashlamp FL.

The capacitor CP is formed from one or more electrolytic capacitors placed in parallel, in series or in series-parallel, the total nominal capacitance of which preferably does not exceed about 13 000 microfarads when it is desired to produce an easily transportable device. However, the nominal capacitance may be very much higher for a device of the professional type. Likewise, the nominal operating voltage of the capacitor or capacitors is at most 400 volts in order to limit their cost. In addition, higher voltages would increase the necessary electrical insulation, which would go counter to the volume reduction of the device. The values indicated above for particular embodiments represent maxima, it being possible to reduce the capacitance or the voltage of the capacitor when the voltage or the nominal capacitance, respectively, approaches these maxima.

The switch SW is a fast-switching electronic switch, operating in around 50 to 300 nanoseconds, and preferably in substantially less than one microsecond. To do this, a switch of the IGBT (insulated gate bipolar transistor) type is chosen, and optionally several switches of this type may be connected in parallel.

The measurement resistor R_m is a resistor of low ohmic value that can withstand high currents. It provides immediately a measurement signal in the form of a voltage UR_m, which is directly proportional to the current passing through it. However, the present invention does not exclude the use of any other current-voltage transducer of analog or digital type, or even any device delivering a direct measurement of the current passing through the flashlamp FL.

The inductor IND is not essential, but, owing to the high-frequency cutoff which takes place in the circuit

in order to control the energy transfer, it is preferred to incorporate a smoothing inductor IND in the CP-SW-R_m-FL loop, for example between the resistor R_m and the flashlamp FL.

A freewheeling diode D is placed in an additional loop R_m-IND-FL-D. The diode D fulfills two roles:

- to transfer energy from the inductor IND to the flashlamp FL when the switch SW is open and the electrical energy is stored in the inductor IND; and
- to limit the voltage spikes across the terminals of the switch SW when it opens, which voltage spikes are generated by the inductor IND, and by the parasitic inductances of the cables, which are relatively large owing to the current of around 250 amps flowing in the main loop.

The regulating elements comprise at least one hysteresis voltage comparator COMP and a logic gate.

The comparator COMP receives as input a reference voltage value U_{ref} delivered by an electronic control module CON and the measurement voltage UR_m generated across the terminals of the resistor R_m. The comparator operates with hysteresis, that is to say that, when the voltage increases, it delivers a signal indicating an overshoot of the reference voltage U_{ref} when the measured voltage UR_m exceeds the reference value plus a specified deviation, and conversely when the voltage decreases, the signal switches when the measured voltage becomes below the reference voltage less a specified deviation.

The reference voltage U_{ref} is adjusted according to the average current with which it is desired to operate the flashlamp FL, especially according to the type of skin, for example by acting on one of the control knobs 4 connected to the control module CON that contains several stored reference voltages.

The logic gate has an input connected to the comparator COMP and an input connected to the control module CON so as to transmit a command for the switch SW to be in the closed state only over the duration of a pulse. For this purpose, the control module CON is designed to deliver a signal T_{pulse} for a specified duration corresponding to the duration of the current pulse, following the actuation of the trigger knob 8.

The pulse duration could be adjusted, however tests show that a constant duration of between 20 and 45 ms, preferably about 35 ms, allows effective hair removal from all types of skin.

Although the present invention does not exclude the control module sending a series of pulse signals so as to produce a series of separate light pulses, in one particular embodiment it is preferred to prevent the emission of a new light pulse before a specified time, called the rest time, which is considerably longer than the duration of a pulse, has elapsed. The rest time programmed into the control module CON is of the order of a few seconds, between one and ten seconds, and preferably about seven seconds. This relatively long rest time ensures that the capacitor has reached its initial charge, that is to say the voltage U_i, without it being necessary to provide a power supply to recharge the high-power capacitor. In addition, this rest time may be profitably employed for cooling the flashlamp FL and the switch SW by natural convection, or possibly by forced convection, but with a low flow rate, this being favorable for reducing the weight and size of the device.

As indicated in figures 5 and 6, prior to the generation of a V/IR light pulse, the capacitor CP is charged to the initial voltage U_i by a power supply device (not shown). The power supply device, which may

be of any known type, generates a DC voltage that is supplied to the terminals of the capacitor CP.

When designing a device according to the present invention, it is necessary firstly to know the desired radiation power P_{pulse} during the pulse, the duration of the pulse T_{pulse} and the length of the flashlamp L_{arc}. With these parameters, it is possible, either by calculation using the formulae supplied by flashlamp manufacturers, or experimentally, to find the potential difference to be applied to the ends of an experimental flashlamp of large diameter and length L_{arc}, in which a stabilized nonconfined electric arc generates radiation of power P_{pulse}. The value found is called U_{critic} - it corresponds to a current I_{critic}. An experiment or a calculation of the same type provides information about the diameter of the electric arc - this diameter is called D_{critic}. After the experimental step, for functional units, $D_{flash} = 1.4 \times D_{critic}$, where D_{flash} is the internal diameter of the flashlamp, is adopted. The final voltage U_f adopted has a value close to $1.25 \times U_{critic}$ and the initial voltage U_i has a value close to $4 \times U_f$. The above coefficients used (1.4, 1.25 and 4) may be varied quite widely, but each of them is greater than 1.

With regard to the main loop of the power circuit CP-SW-R_m-IND-FL, it is preferable, without being limiting, to have an arrangement of the elements in the following order: the negative pole of the capacitor CP, the switch SW, the measurement resistor R_m (or another current-voltage transducer), the inductor IND, the flashlamp FL (negative pole on the inductor side) and the positive pole of the capacitor CP. The additional loop is formed from the measurement resistor R_m (or another current-voltage transducer), the inductor IND, the flashlamp FL and the diode D, the diode D having, in this case, its cathode connected to the positive poles of the flashlamp FL and of the capacitor CP.

The inductance of IND may be such that, when a current I_{critic} flows through the inductor it stores electrical energy of between 1/100 and 1/1000 of the electrical energy transferred to the flashlamp FL during each V/IR light pulse.

To start a pulse, the flashlamp FL is turned on, for example by means of a very high-voltage pulse using a conventional method known for flashlamps, and to ensure that the switch SW is closed. At this moment, the current, initially zero, increases in the loop CP-SW-R_m-IND-FL since the electric arc increases in section and the inductor IND slows down the change in the current. This current creates a voltage difference UR_m across the terminals of R_m. When UR_m has exceeded U_{ref}, the output of the comparator COMP changes state. This change in state causes the switch SW to open. Once the switch SW is open, the current in the loop R_m-IND-FL-D, and also the voltage UR_m, decreases down to a threshold which again causes switching of the output of the comparator COMP. This switching causes the switch SW to close if the pulse time T_{pulse} has not elapsed. For a complete pulse, these cycles are repeated as many times as necessary, for example around 100 times for a pulse duration of 35 ms. It should be noted that the current flowing in the flashlamp does not drop to a zero value immediately after the switch opens, even in the absence of the inductor IND. This is because, given the high currents and voltages in the main and secondary loops, and also the ionization effects in the flashlamp, the wiring and the flashlamp store a certain amount of electrical energy, which is recovered when the switch SW opens. In contrast, the current flowing through the capacitor CP that is outside the secondary loop very rapidly drops to zero. Therefore closely spaced individual current pulses are observed at the terminals of the capacitor.

Within each cycle, the current flowing through R_m (and therefore that flowing through the lamp FL) is regulated about the current I_{critic}, with a ripple whose amplitude depends on the hysteresis of the comparator COMP. This regulation is carried out over substantially the entire duration of the pulse, that is to say over the duration of the pulse less the duration of the flashlamp ignition and current extinction phases, which are very short, of the order of 100 microseconds, compared with the duration of the pulse, of the order of 40 milliseconds.

The amplitude of the current ripples in the flashlamp FL, and consequently of the power shown schematically in figure 6, is ±10%, but amplitudes greater than ±30% may be permitted, given their very short duration and the rapid succession of peaks and troughs. However, it is important that, over a significant duration relative to the thermal inertia of skin tissue, especially over a duration of 1 ms or the duration of an open/close cycle of the switch SW, the average power of the pulse P_{pulse} be close to the power corresponding to the regulation current I_{critic}, and preferably equal to the latter to within ±10%. Moreover, better skin response is obtained if the average value of the current flowing through the flashlamp decreases only slightly, by less than 10%, between the start and the end of the pulse.

Since the instantaneous power values involved are very high, particular attention must be paid to the switch SW which is, as mentioned, a fast on/off switch. The word "fast" relates to its changes of state, which last a few hundred nanoseconds, but during each switching operation there is very considerable instantaneous heat dissipation within the switch. The average heat dissipation remains acceptable if the succession of switching operations is not too rapid. To guarantee this condition, the hysteresis in the control of the current through the flashlamp FL may be increased, or

it is possible to incorporate, into the control for the switch SW, a delay $T_{prevent}$ (not shown) of a few tens of microseconds which keeps the switch SW in the open state after each transition from the closed state to the open state. In this way, the switch SW cannot be stressed for very rapid close/open/close cycles, and when the delay $T_{prevent}$ occurs, it contributes to reducing the energy transfer power to the flashlamp, which may impair the quality of the functional result, but places the switch SW in a better safety-protected working range. When the delay $T_{prevent}$ occurs, the current flowing through the flashlamp FL decreases below the value corresponding to the command for closing the switch generated by the hysteresis comparator, and may become zero. However, in this case the current in the flashlamp is zero only over a time shorter than the delay, which is itself shorter than the extinction time of the flashlamp. The light power emitted by the flashlamp therefore does not drop to zero, and increases after the end of the delay since the flashlamp remains conducting. The light pulse is not interrupted and this reduction in or cancellation of the current in the flashlamp has no deleterious effect on the hair removal, given its brevity.

The part of the circuits that generates the delay $T_{prevent}$, if this optional part exists, is placed in the signal chain close to the switch SW. In this way, when a possible parasitic signal causing interference in the circuits occurs, the switch SW has the best chance of being protected against accidental stressing at too high a frequency. In the absence of exceptional electromagnetic interference, the safety provided by $T_{prevent}$ does not come into play. As an example, this delay $T_{prevent}$ may be implemented by a signal sent by the control module CON to an additional logic gate, which also receives the signal from the logic gate shown in figure 4.

With such a regulating method, it is theoretically possible to choose a value of U_i that is very high relative to U_f, for example $U_i = 10 \times U_f$. In this case, the capacitor CP would be used at 99%, but the switch SW would have to withstand a high voltage and its cost would increase excessively for certain embodiments. A good compromise between the technical and financial aspects consists in choosing a U_i/U_f ratio of between 3 and 5, or even 6. In figure 5, with $U_i = 4 \times U_f$, after a pulse only 1/16th of the energy initially stored in CP remains. The utilization factor of CP is 15/16, i.e. 93.7%, compared with 16% in the example mentioned relating to the prior art in figure 2. With a U_i/U_f ratio of 2, a utilization factor of the capacitor CP of greater than 60% is already obtained.

Figure 6 shows by way of indication a result that can be obtained with the instantaneous power remaining within the ±10% margin of its nominal value during a V/IR light discharge, while the CP utilization factor is 93.7% during the same discharge.

The invention makes it possible to produce smaller devices that are more economic to manufacture and consume lighter lamps than the devices of the prior art. By choosing one or more suitable capacitors and by optimizing their use thanks to the various arrangements of the present invention, it is possible to mass-produce a device with a weight of less than 2 kg. By limiting the operating voltage of the capacitor(s) and thanks to the high-frequency cut-off regulation, the box 2, which contains the power supply for recharging the capacitor, the capacitor, the switch, the resistor, the inductor and the control module, is of small dimensions, so that the volume of the box is less than 5 liters.

CLAIMS

1. A hair-removal device for local skin application, designed to emit at least one light pulse generated by an electric current pulse passing through a flashlamp (FL) forming an electric arc therein, this current coming from the discharge of at least one capacitor (CP) and being controlled by a fast-switching on/off electronic switch (SW), these three elements being placed in a main loop (CP-SW-FL), characterized in that, during each discharge of the capacitor, the current passing through the flashlamp (FL) generates a measurement signal (UR_m) representative of said current passing through the flashlamp, and in that said measurement signal (UR_m) is compared with a reference value (U_{ref}) by a hysteresis comparator (COMP) in order to set said switch (SW) in the open or closed state and to regulate said current passing through the flashlamp (FL) by its high-frequency cutoff around a defined current (I_{critic}) through substantially the entire duration of said current pulse.

2. The device as claimed in claim 1, wherein the measurement signal is a measurement voltage (UR_m) proportional to the current passing through the flashlamp (FL), which voltage is delivered by a current-voltage transducer, said current-voltage transducer preferably being a resistor (R_m) connected in series in the main loop (CP-SW-FL).

3. The device as claimed in claim 2, wherein a freewheeling diode (D) is incorporated into an additional loop (R_m-FL-D) comprising, in common with the main loop, the flashlamp (FL) and the current-voltage transducer (R_m).

4. The device as claimed in any one of claims 1 to 3, wherein the main loop (CP-SW-FL) further includes an inductor (IND).

5. The device as claimed in any one of the preceding claims, wherein the hysteresis comparator (COMP) and the reference value (U_{ref}) are chosen so as to regulate the current passing through the flashlamp (FL) to a value substantially below the value of the current for which the expansion of the electric arc reaches the inner walls of the flashlamp (FL).

6. The device as claimed in any one of the preceding claims, wherein said at least one capacitor (CP) is chosen so that the ratio of the initial voltage (U_i) across its terminals before discharge to the final voltage (U_f) at the end of the current pulse is between 2 and 6, and preferably about 4.

7. The device as claimed in any one of the preceding claims, wherein said at least one capacitor has a capacitance at most equal to 13 000 microfarads and a nominal voltage at most equal to 400 volts, said at least one capacitor preferably being an electrolytic capacitor.

8. The device as claimed in any one of the preceding claims, wherein the capacitance of the capacitor (CP) is chosen so that the mean value of the current flowing through the flashlamp (FL), measured over a period of one millisecond at the end of the current pulse, is between 90% and 100% of the mean value of the current measured over the same period at the start of the current pulse.

9. The device as claimed in any one of the preceding claims, wherein the electronic switch (SW) is chosen so as to have a switching time considerably shorter than one microsecond, said switch preferably being an IGBT.

10. The device as claimed in any one of the preceding claims, wherein an electronic control module (CON) is designed to deliver the reference value (U_{ref}) to the hysteresis comparator (COMP) and designed to deliver a current pulse in the main loop over a specified pulse duration, said pulse duration being between 20 ms and 45 ms, and preferably equal to about 35 ms.

11. The device as claimed in claim 10, wherein the control module (CON) is designed to introduce, into the fast-switching switch (SW), a delay ($T_{prevent}$) of specified duration at each opening of this switch (SW), during which it is prevented from switching again to the closed state, the specified duration being significantly longer than the switching time of the switch (SW) but shorter than the time needed for the flashlamp (FL) to be turned off.

12. The device as claimed in claim 10 or 11, wherein the control module (CON) is designed so as not to cause a new current pulse to be emitted before a specified time, called the rest time, has elapsed since the preceding current pulse, the specified rest time being between one second and ten seconds, and preferably about seven seconds.

13. The device as claimed in any one of the preceding claims, wherein said at least one capacitor (CP), the electronic switch (SW) and the hysteresis comparator (COMP) are housed in a same casing, said casing having a volume of less than five liters.

14. The device as claimed in any one of the preceding claims, wherein the weight of the overall device is at most equal to two kilograms.

15. A method of employing a hair-removal device designed to emit at least one light pulse generated by

an electric current pulse passing through a flashlamp (FL) forming an electric arc therein, wherein at least one capacitor (CP), designed to deliver the current passing through the flashlamp, and a fast-switching on/off electronic switch (SW) are provided, the capacitor (CP), the electronic switch (SW) and the flashlamp (FL) forming a main loop (CP-SW-FL), characterized in that it comprises, while generating the electric current pulse, the steps of:

- generating a measurement signal (UR_m) representative of the current passing through the flashlamp (FL);
- comparing, with hysteresis, the measurement signal (UR_m) with a reference value (U_{ref});
- closing the electronic switch (SW) if the comparison between the measurement signal (UR_m) and the reference value (U_{ref}) indicates that the current passing through the flashlamp (FL) is below a specified current (I_{critic}); or
- opening the electronic switch (SW) if the comparison between the measurement signal (UR_m) and the reference value (U_{ref}) indicates that the current passing through the flashlamp (FL) is above the specified current (I_{critic}), so as to regulate said current passing through the flashlamp (FL) by high-frequency cutoff thereof around the specified current (I_{critic}).

16. The method as claimed in claim 15, wherein, each time the switch (SW) is opened, a delay step ($T_{prevent}$) of specified duration is provided, during which the switch (SW) is prevented from switching again to the closed state, the specified time being significantly longer than the switching time of the switch (SW) but shorter than the time needed for the flashlamp to be turned off.

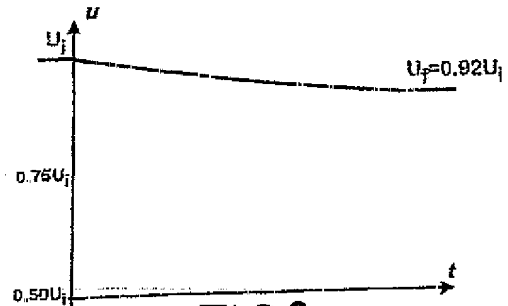


FIG2.

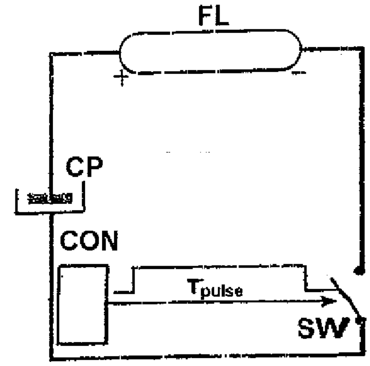


FIG.1.

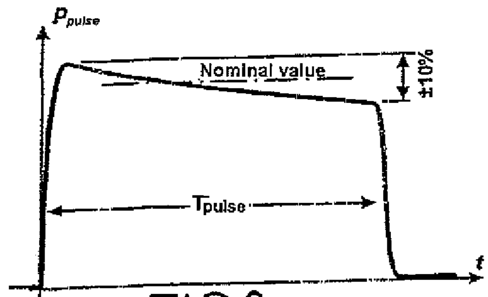


FIG.3.
PRIOR ART

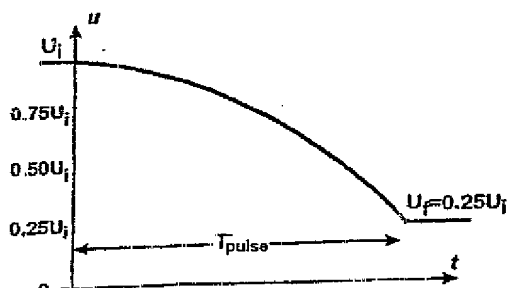


FIG5.

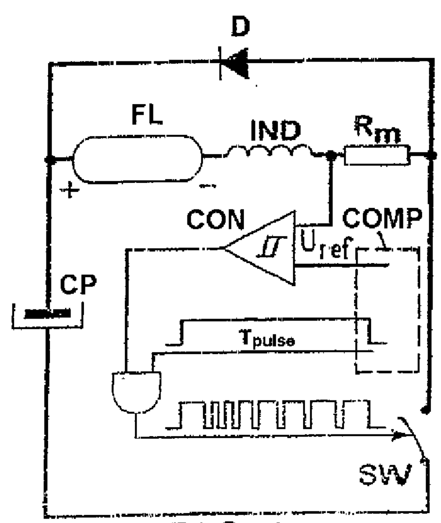


FIG.4.

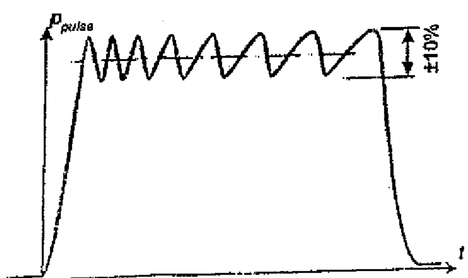


FIG6.

FIG.7.